ORRG

https://orrg.eu/

Introduction to Open and Reproducible Research

Tony Ross-Hellauer
Open & Reproducible Research Group
Graz University of Technology & Know-Center

TU Graz

Know Center

Open Science

What is Open Science?

Definition per 2021 *UNESCO Recommendation on Open Science,* Open Science aims to:

- "make multilingual scientific knowledge openly available, accessible and reusable for everyone"
- "increase scientific collaborations and sharing of information for the benefits of science and society"
- "open the processes of scientific knowledge creation, evaluation and communication to societal actors beyond the traditional scientific community."

UNESCO Recommendation on Open Science

https://unesdoc.unesco.org/ark:/48223/pf0000379949

What is Open Science?

Definition per 2021 *UNESCO Recommendation on Open Science,* Open Science aims to:

- “make multiling
  available, acce
- “increase scier
  information for
  society”
- “open the processes of scientific knowledge creation, evaluation and communication to societal actors beyond the traditional scientific community.”

Why?

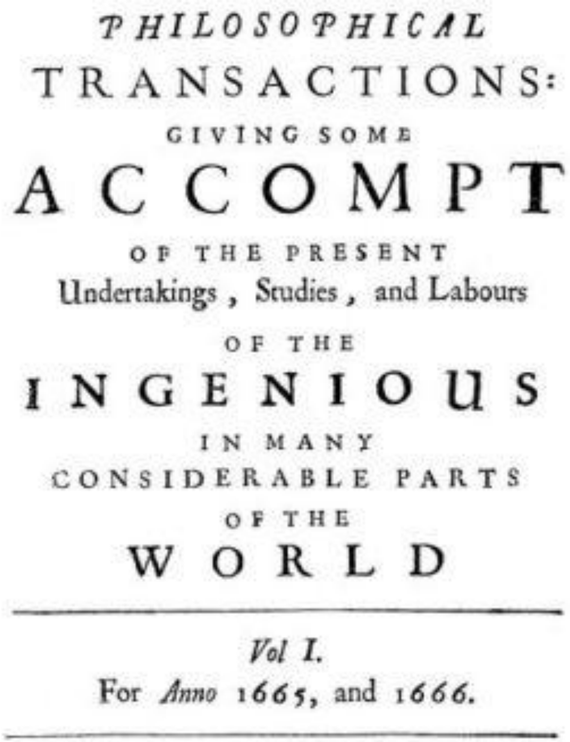
https://unesdoc.unesco.org/ark:/48223/pf0000379949

Because we can?

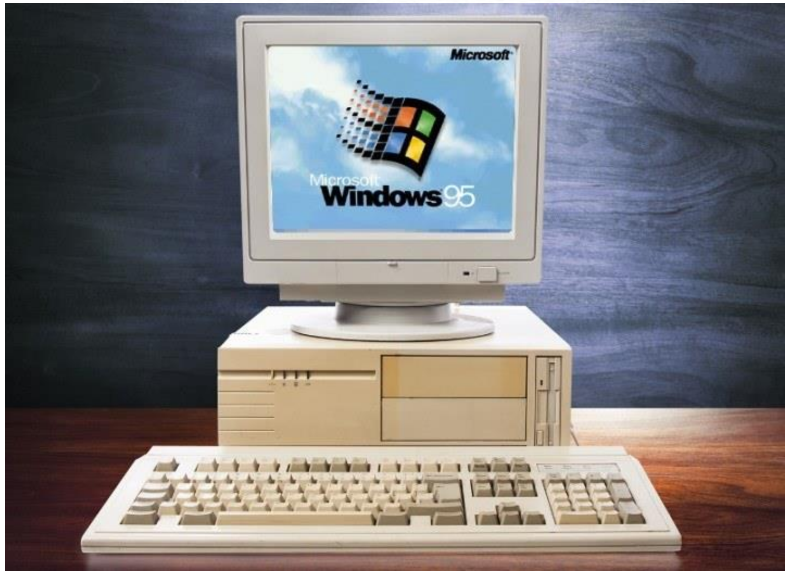
The current state of scholarly communication?

A 19th century process applied to a 17th century communication format

Slowly but surely adapting to web technologies from 1995


PHILOSOPHICAL
TRANSACTIONS:
GIVING SOME
ACCOMPT
OF THE PRESENT
Undertakings, Studies, and Labours
OF THE
INGENIOUS
IN MANY
CONSIDERABLE PARTS
OF THE
WORLD

Vol I.
For *Anno* 1665, and 1666.



Because the way we do things atm isn't going great?

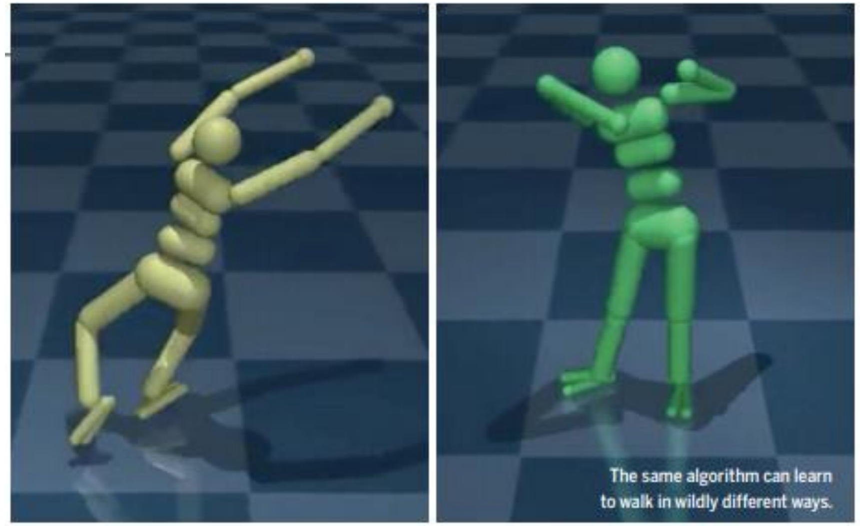
Why Most Published Research Findings Are False

John P. A. Ioannidis

nature REVIEWS DRUG DISCOVERY

Believe it or not: how much can we rely on published data on potential drug targets?

Florian Prinz, Thomas Schlange & Khusru Asadullah



COMPUTER SCIENCE

Artificial intelligence faces reproducibility crisis

Unpublished code and sensitivity to training conditions make many claims hard to verify

BMJ

BMJ 2014;348:g3725 doi: 10.1136/bmj.g3725 (Published 13 June 2014)

Evidence based medicine: a movement in crisis?

Trisha Greenhalgh and colleagues argue that, although evidence based medicine has had many benefits, it has also had some negative unintended consequences. They offer a preliminary agenda for the movement's renaissance, refocusing on providing useable evidence that can be combined with context and professional expertise so that individual patients get optimal treatment

Power failure: why small sample size undermines the reliability of neuroscience

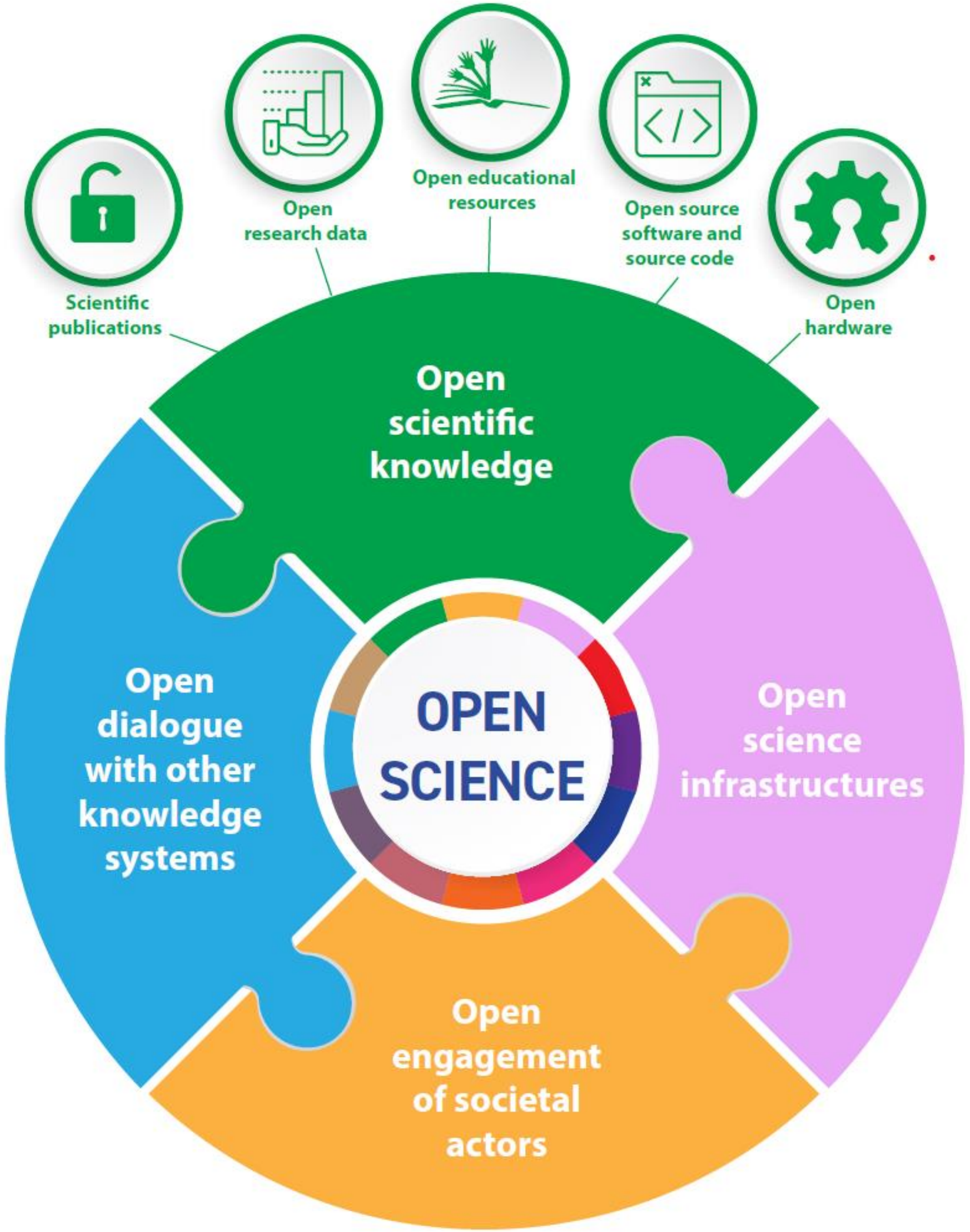
Katherine S. Button[1,2], John P. A. Ioannidis[3], Claire Mokrysz[1], Brian A. Nosek[4], Jonathan Flint[5], Emma S. J. Robinson[6] and Marcus R. Munafò[1]

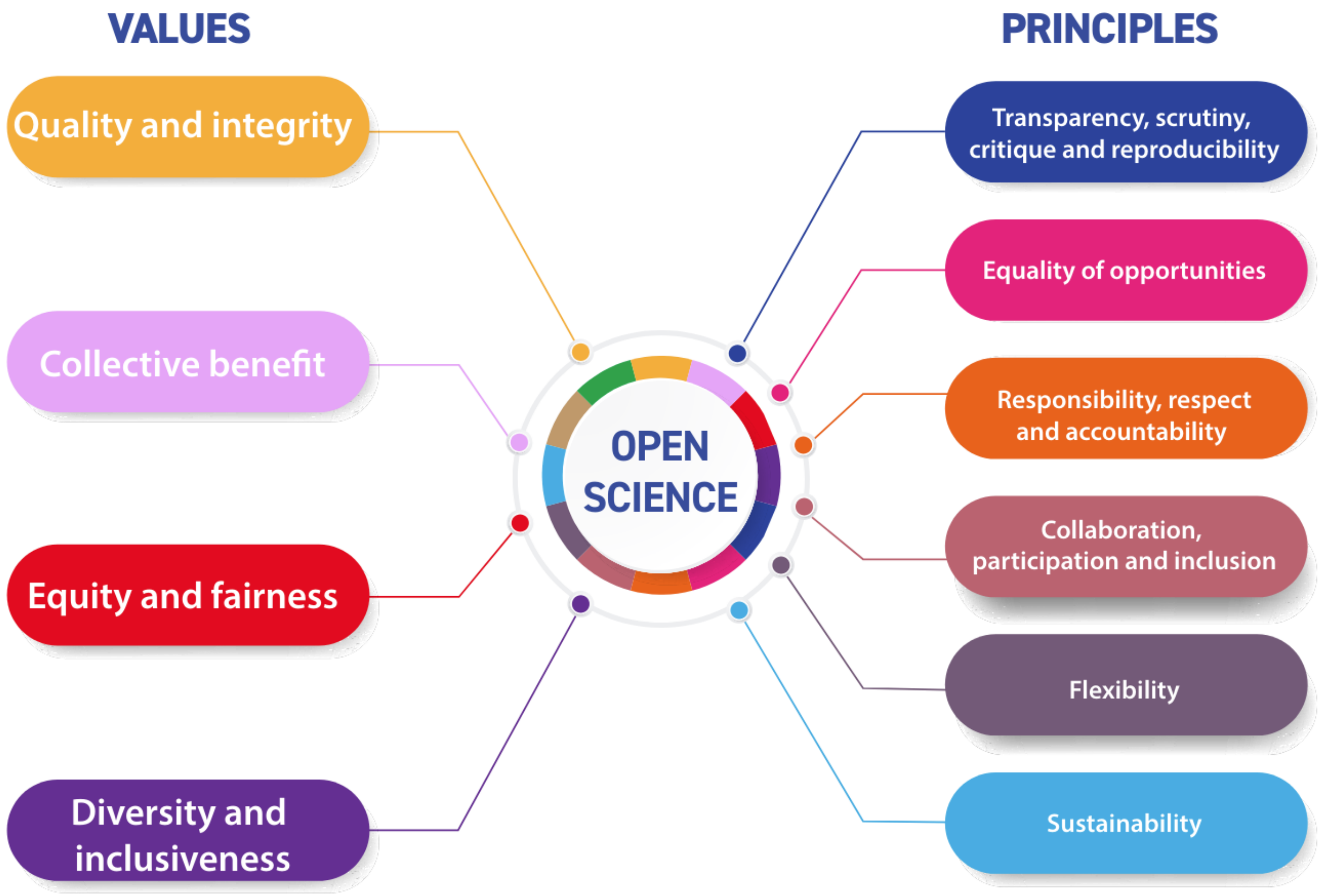
Because we should?

Publicly-funded knowledge is a public good and should be accessible to everyone, right?

- Article 27 of the Universal Declaration of Human Rights: “Everyone has the right freely to … share in scientific advancement and its benefits.”
- Article 15 of the International Covenant on Economic, Social and Cultural Rights: “recognize the right of everyone … To enjoy the benefits of scientific progress and its applications”

Open Science is a diverse bunch of *practices* and *principles*

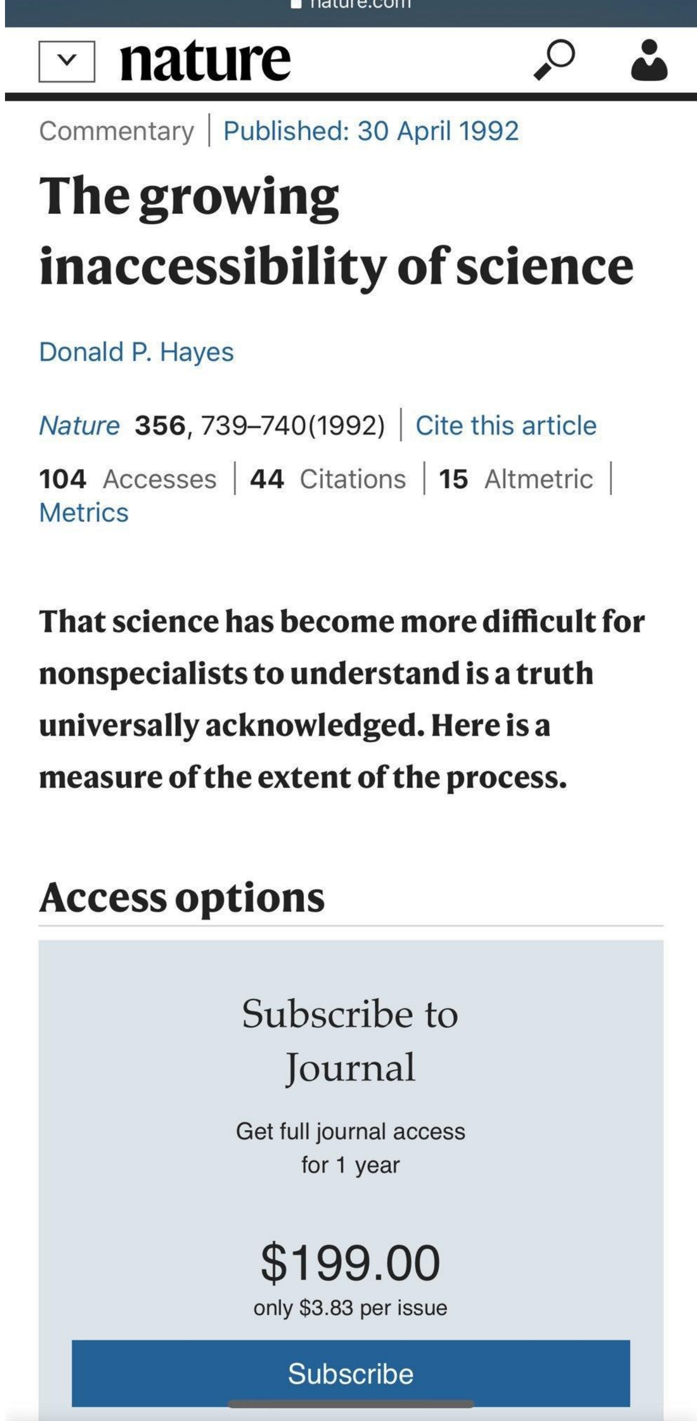




Images from UNESCO Recommendation, CC BY SA

Open Access

For researchers, getting published is like going to a restaurant, bringing all of your own ingredients, cooking the meal yourself, and then being charged $40 for a waiter to bring it out on a plate for you.



nature

Commentary | Published: 30 April 1992

The growing inaccessibility of science

Donald P. Hayes

Nature **356**, 739–740(1992) | Cite this article

104 Accesses | **44** Citations | **15** Altmetric | Metrics

That science has become more difficult for nonspecialists to understand is a truth universally acknowledged. Here is a measure of the extent of the process.

Access options

Subscribe to Journal

Get full journal access for 1 year

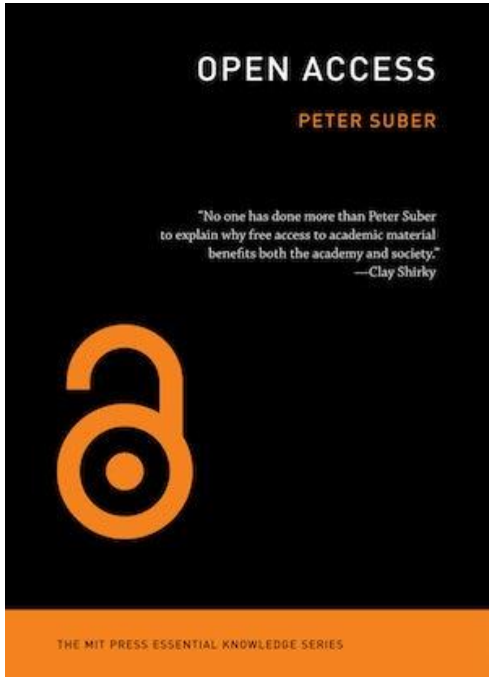
$199.00

only $3.83 per issue

Subscribe

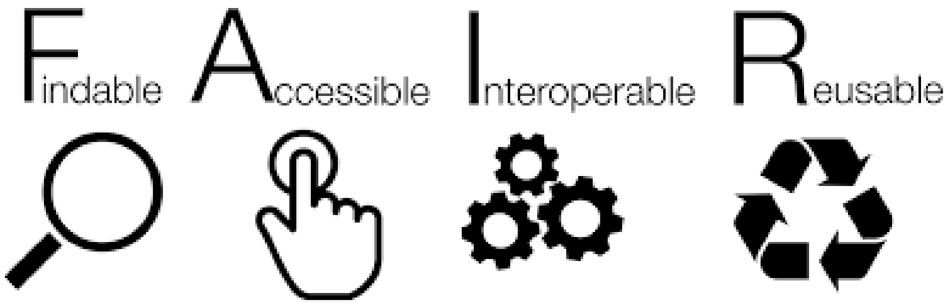
Open Access

- Aim: Make scientific literature Open Access (OA)
  - “Open access (OA) literature is digital, online, free of charge, and free of most copyright and licensing restrictions” (Suber 2012)
- Two main routes:
  - Journals publish articles OA (gold OA)
  - Authors upload copies of articles to repositories (green OA)
- Movement that dates back to the 1990s
  - Catalyst: Budapest Open Access Initiative (Chan et al. 2002)

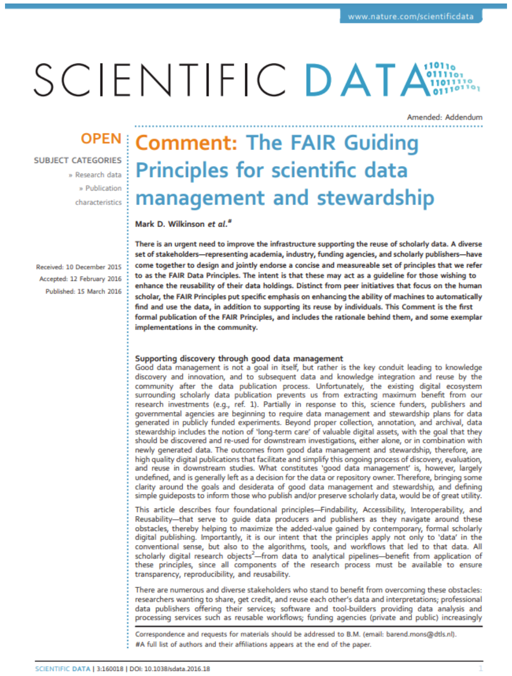


Chan, L. et al. 2002. “Budapest Open Access Initiative.” Budapest Open Access Initiative. February 14, 2002. http://www.budapestopenaccessinitiative.org/read
Suber, P. 2012. Open Access. MIT Press. Cambridge, MA.

Open and FAIR data



- Aim: To enable re-use and reproducibility by making research data as open as possible but as closed as necessary
- There are sometimes good reasons for not making data open (sensitive data, rights issues, security, competition*)
- FAIR is a framework for ensuring data is (if not open), at least *findable*, *accessible*, *interoperable* and *re-usable*



www.nature.com/scientificdata

SCIENTIFIC DATA

Amended: Addendum

OPEN

SUBJECT CATEGORIES
» Research data
» Publication characteristics

Received: 10 December 2015
Accepted: 12 February 2016
Published: 15 March 2016

Comment: The FAIR Guiding Principles for scientific data management and stewardship

Mark D. Wilkinson *et al.*#

There is an urgent need to improve the infrastructure supporting the reuse of scholarly data. A diverse set of stakeholders—representing academia, industry, funding agencies, and scholarly publishers—have come together to design and jointly endorse a concise and measureable set of principles that we refer to as the FAIR Data Principles. The intent is that these may act as a guideline for those wishing to enhance the reusability of their data holdings. Distinct from peer initiatives that focus on the human scholar, the FAIR Principles put specific emphasis on enhancing the ability of machines to automatically find and use the data, in addition to supporting its reuse by individuals. This Comment is the first formal publication of the FAIR Principles, and includes the rationale behind them, and some exemplar implementations in the community.

Supporting discovery through good data management

Good data management is not a goal in itself, but rather is the key conduit leading to knowledge discovery and innovation, and to subsequent data and knowledge integration and reuse by the community after the data publication process. Unfortunately, the existing digital ecosystem surrounding scholarly data publication prevents us from extracting maximum benefit from our research investments (e.g., ref. 1). Partially in response to this, science funders, publishers and governmental agencies are beginning to require data management and stewardship plans for data generated in publicly funded experiments. Beyond proper collection, annotation, and archival, data stewardship includes the notion of 'long-term care' of valuable digital assets, with the goal that they should be discovered and re-used for downstream investigations, either alone, or in combination with newly generated data. The outcomes from good data management and stewardship, therefore, are high quality digital publications that facilitate and simplify this ongoing process of discovery, evaluation, and reuse in downstream studies. What constitutes 'good data management' is, however, largely undefined, and is generally left as a decision for the data or repository owner. Therefore, bringing some clarity around the goals and desiderata of good data management and stewardship, and defining simple guideposts to inform those who publish and/or preserve scholarly data, would be of great utility.

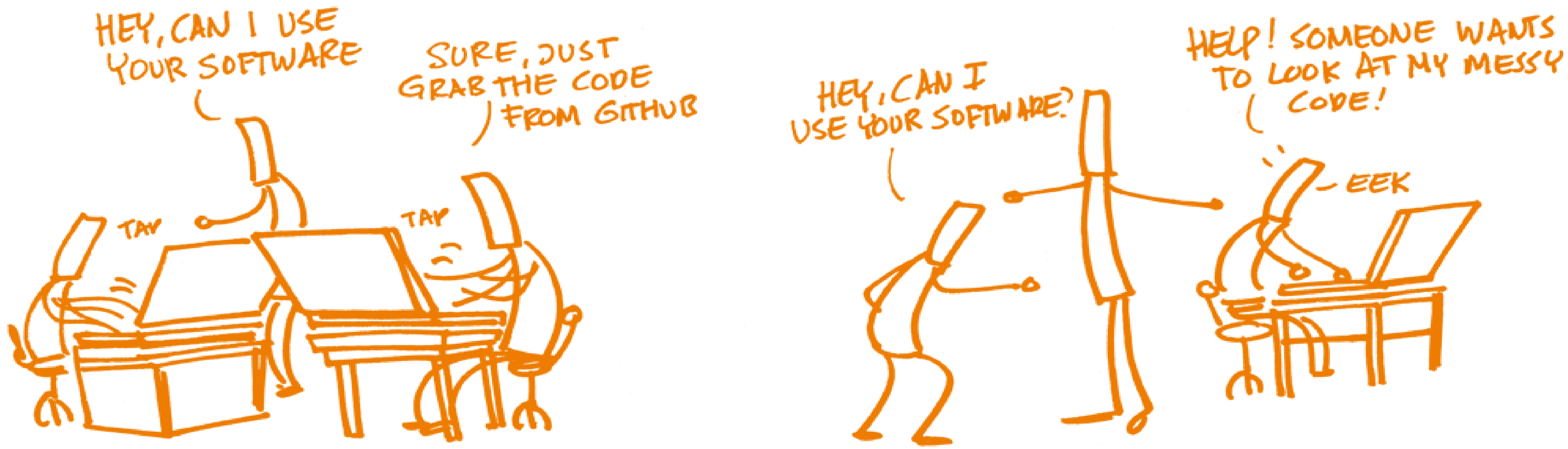
This article describes four foundational principles—Findability, Accessibility, Interoperability, and Reusability—that serve to guide data producers and publishers as they navigate around these obstacles, thereby helping to maximize the added-value gained by contemporary, formal scholarly digital publishing. Importantly, it is our intent that the principles apply not only to 'data' in the conventional sense, but also to the algorithms, tools, and workflows that led to that data. All scholarly digital research objects[2]—from data to analytical pipelines—benefit from application of these principles, since all components of the research process must be available to ensure transparency, reproducibility, and reusability.

There are numerous and diverse stakeholders who stand to benefit from overcoming these obstacles: researchers wanting to share, get credit, and reuse each other's data and interpretations; professional data publishers offering their services; software and tool-builders providing data analysis and processing services such as reusable workflows; funding agencies (private and public) increasingly

Correspondence and requests for materials should be addressed to B.M. (email: barend.mons@dtls.nl).
#A full list of authors and their affiliations appears at the end of the paper.

SCIENTIFIC DATA | 3:160018 | DOI: 10.1038/sdata.2016.18 1

Wilkinson, M.D. et al. 2016. "The FAIR Guiding Principles for Scientific Data Management and Stewardship." *Scientific Data*. https://doi.org/10.1038/sdata.2016.18



Open source code and software

- Open Source is freely available software that can be modified and redistributed
- Software plays a pivotal role in research methods across many/most academic disciplines
- Sharing analysis scripts and code underpinning scientific publications helps ensure transparency, computational reproducibility and aids re-use
- Preferring open source software for research overcomes proprietary software costs, limitations on transparency of functionality, avoids vendor lock-in, and is also often more responsive to community needs.
  - C.f., https://openscience-utrecht.com/free-libre-and-open-source-software-for-research/

Open methods, protocols & materials

Making research methodologies, protocols, and materials freely accessible to enhance reproducibility, transparency, and collaboration

- Methods: Enhanced descriptions of experimental procedures, computational algorithms, or data analysis techniques
  - Open Notebooks: Digital platforms (e.g., Jupyter) where researchers transparently share their ongoing processes, data, and findings in real-time,
- Protocols: Step-by-step procedures for experiments, ensuring consistency and reproducibility
  - Protocol.io: A platform for sharing and collaborating on research protocols
- Materials: Information about reagents (chemicals, enzymes, antibodies, etc.) and other physical materials or resources used in research
  - C.f., Open Materials database: https://openmaterialsdb.se/

Citizen Science - Engaging the public in research

- Citizen science involves the general public in scientific research activities, often through data collection, analysis, or reporting
- Key Benefits:
  - Widens data collection: Engages diverse participants, enabling large-scale and geographically widespread data collection (e.g., environmental monitoring)
  - Enhances scientific literacy: Bridges the gap between scientists and the public, fostering science education and literacy
  - Many hands: Distributed data analysis where, e.g., manual classification of galaxies done by thousands of volunteers (Galaxy Zoo) (can now be combined with Machine Learning techniques)
- Example: Zooniverse platform: zooniverse.org

Open Peer Review

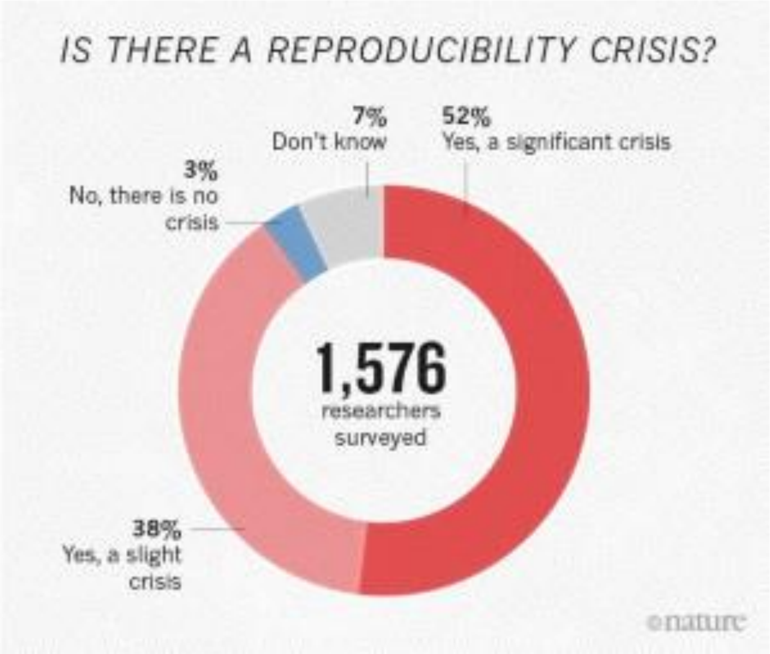
- Bringing Open Science principles to the ways research and researchers are assessed
- Peer review is our primary quality assurance mechanism
- Scholarly works are scrutinised by others (“experts”), whose feedback and judgements are used to improve works and make decisions regarding selection
- Peer review is felt essential (though often as ‘least-worst option’), and generally highly valued, but we know it has multiple issues, e.g.:
    - Accountability
    - Biases
    - Error detection
    - Incentives
    - Time
    - Wasted effort

Reproducibility

What is reproducibility?

- At its highest level, just obtaining consistent results when repeating experiments, observations or analyses
- Often considered a cornerstone of ***scientific*** enquiry
- Definitions vary (a lot)
  - Not only in using the same words for different things (reproducibility / replication) but also in taxonomies for the various aspects of research that can be made reproducible/replicable
- Key distinction between:
  - *Methods reproducibility:* Work that is reproducible in principle, meaning that there is sufficient documentation and sharing of methods, protocols, data, code, etc. to enable the work to be reproduced.
  - *Results reproducibility:* Work that actually successfully reproduces/replicates when a study is repeated, i.e., the results are found to be sufficiently similar across both studies.

Reproducibility of research is in question



Why Most Published Research Findings Are False

John P. A. Ioannidis

COMPUTER SCIENCE

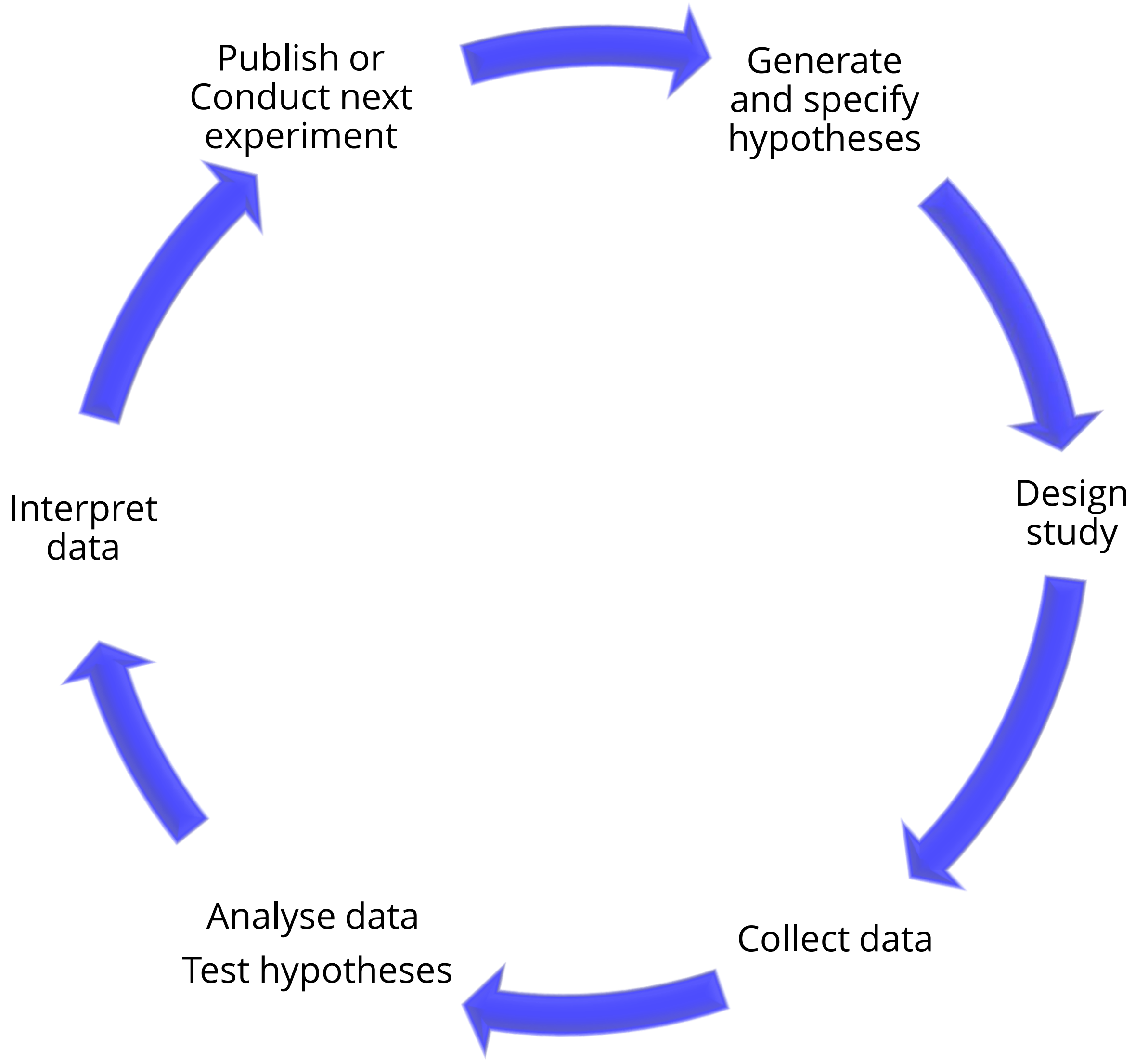
Artificial intelligence faces reproducibility crisis

Unpublished code and sensitivity to training conditions make many claims hard to verify

Causes

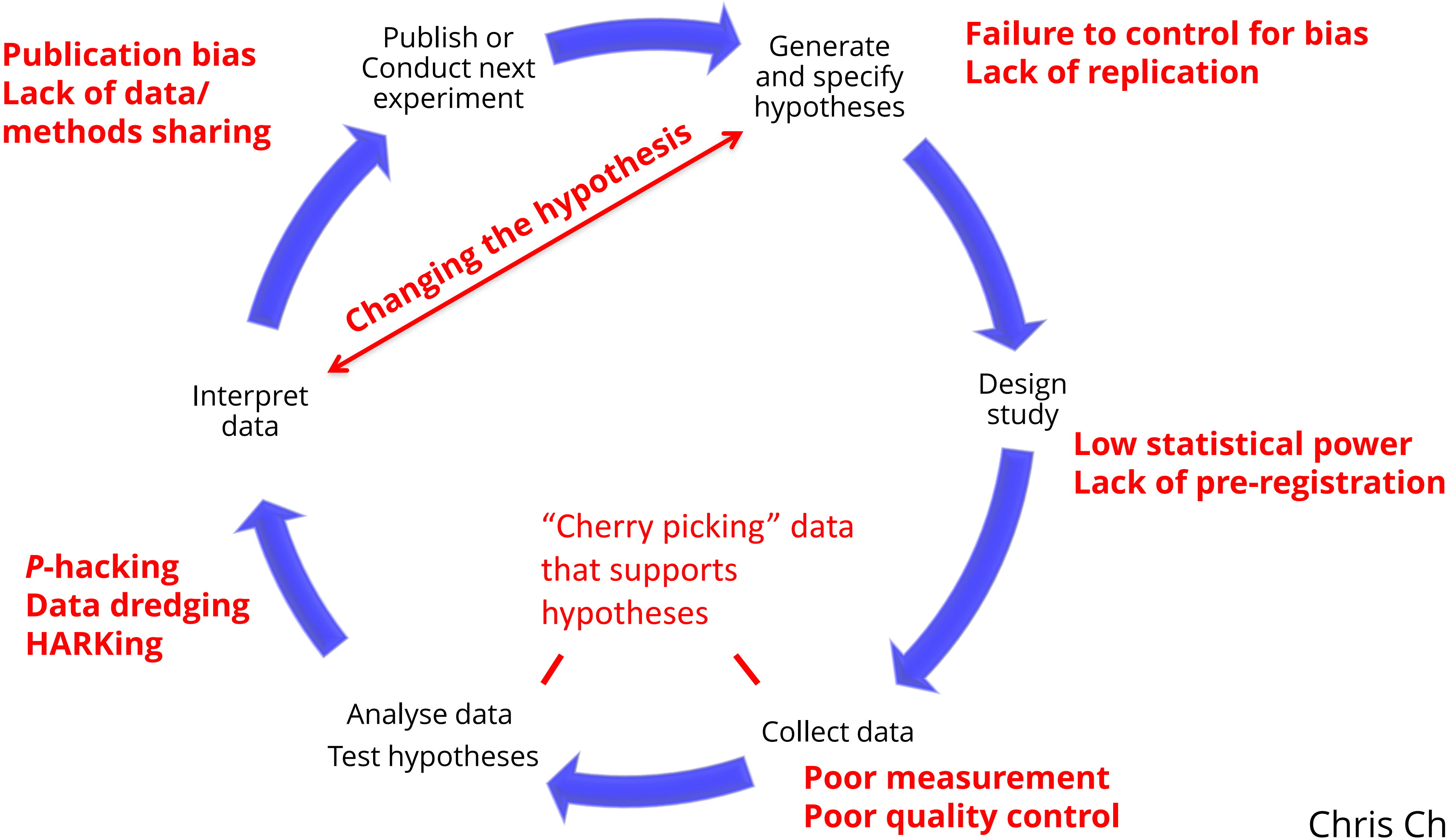
- Poor reporting of methods
- Poor design (e.g., underpowered studies)
- Inadequate sharing of raw and processed data, code, materials
- Lack of standardisation (variation in protocols, equipment, analytical methods)
- Lack of (incentives for) reproduction/replication studies
- Publication bias (positive results over null or negative findings)
- Questionable research practices (incl. p-hacking, HARKing, data leakage)
- Researcher social/cognitive biases
- Constraints of time/resources

The (ideal) hypothetico-deductive model of research



Chris Chambers
osf.io/dfr85

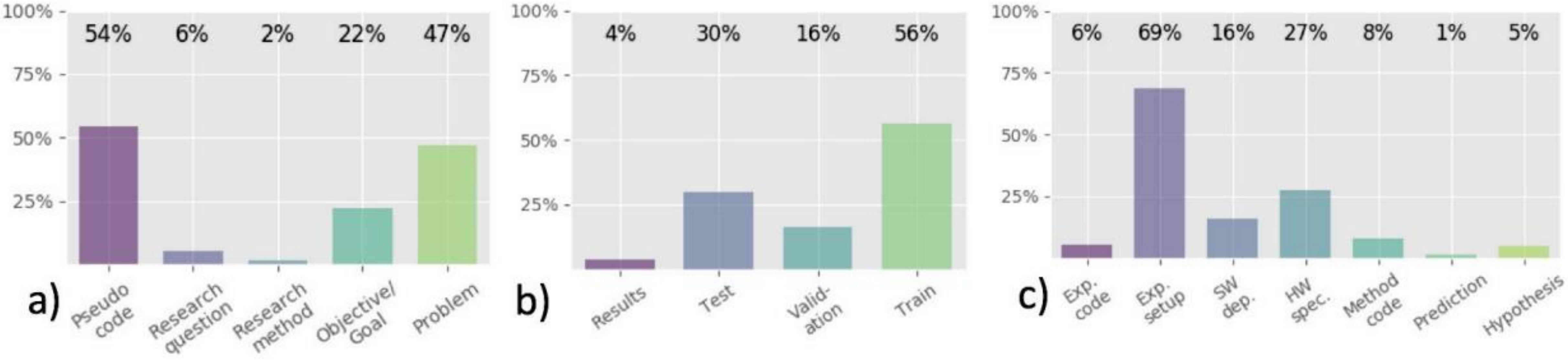
Where things go wrong (hint: it's the humans)



Chris Chambers
osf.io/dfr85

Reproducibility as (in part) a *documentation* issue (hence the importance of Open Science)

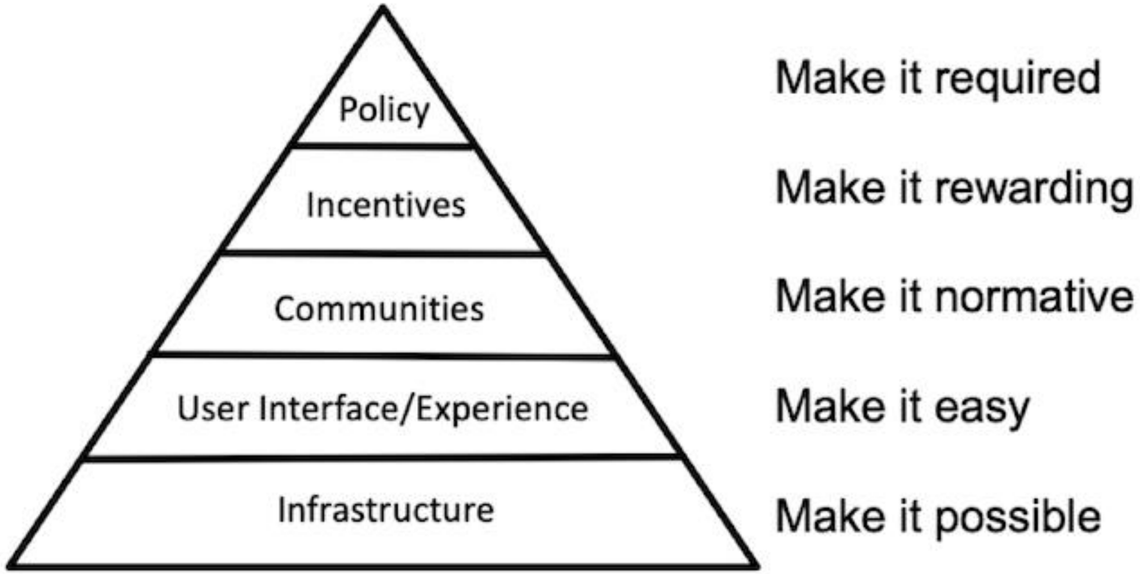
- Many of the issues underlying poor levels of reproducibility relate to poor documentation
- (Gundersen and Kjensmo 2018), examining AI research: "The three degrees of reproducibility are defined by which documentation is used to reproduce the results."



Gundersen O.E. 2018. "State of the Art: Reproducibility in Artificial Intelligence." Proceedings of the AAAI Conference on Artificial Intelligence 32 (1). https://ojs.aaai.org/index.php/AAAI/article/view/11503.

An issue of Research Culture?

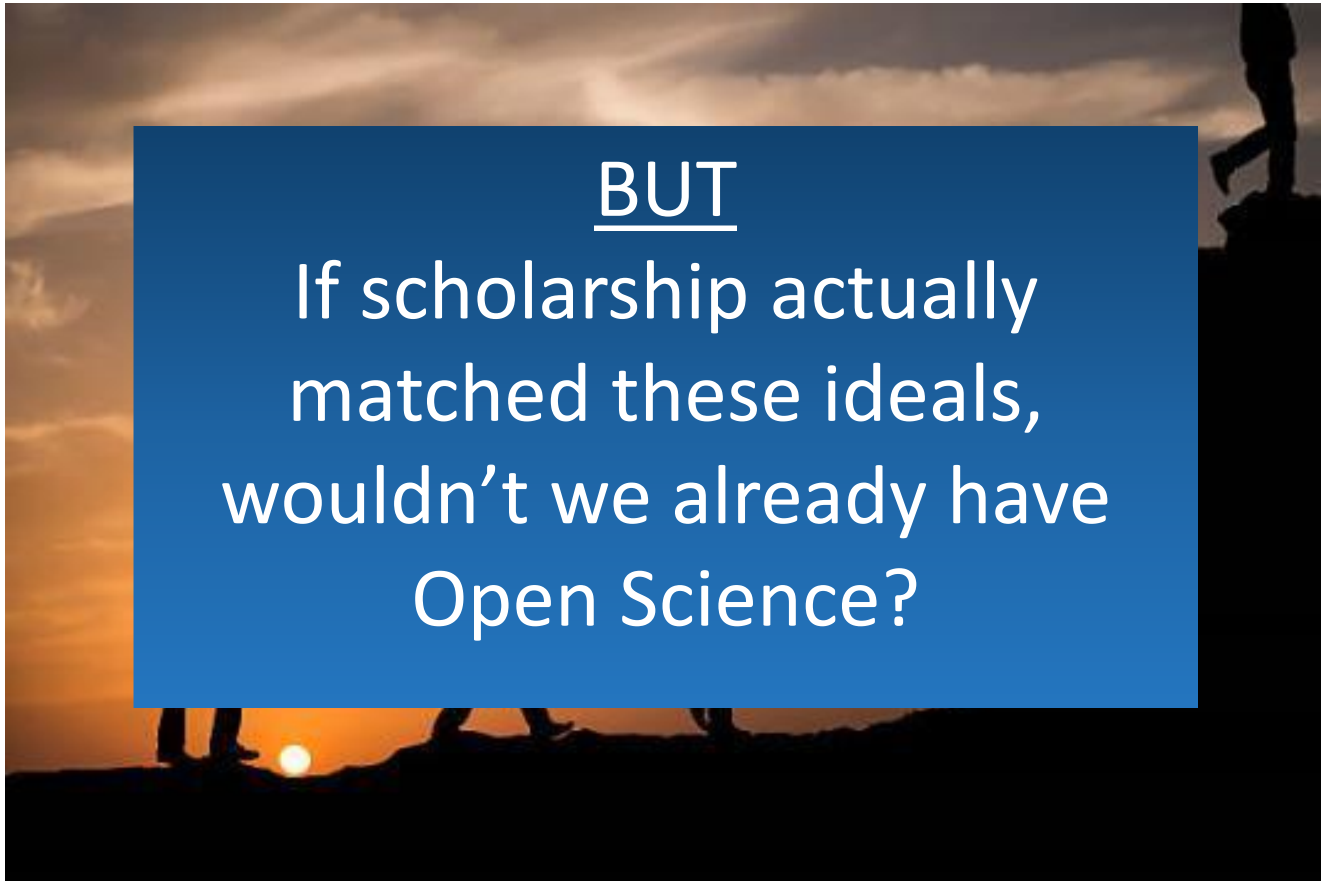
- Lack of uptake of Open Science practices is in large part due to a lack of incentives
- Current cultures in research prioritise competition over collaboration and publication of flashy, counter-intuitive findings in prestigious venues
- Why? And how does this harm reproducibility? …



https://www.cos.io/blog/strategy-for-culture-change

Research culture: Mertonian norms – “ the ethos of modern science”?

- Commun(al)ism
- Universalism
- Disinterestedness
- Organised skepticism



BUT

If scholarship actually matched these ideals, wouldn’t we already have Open Science?

Merton (1942) The Normative Structure of Science

Anti-norms – a more realistic picture?

- Particularism
- Competition
- Self-interestedness
- Organized dogmatism

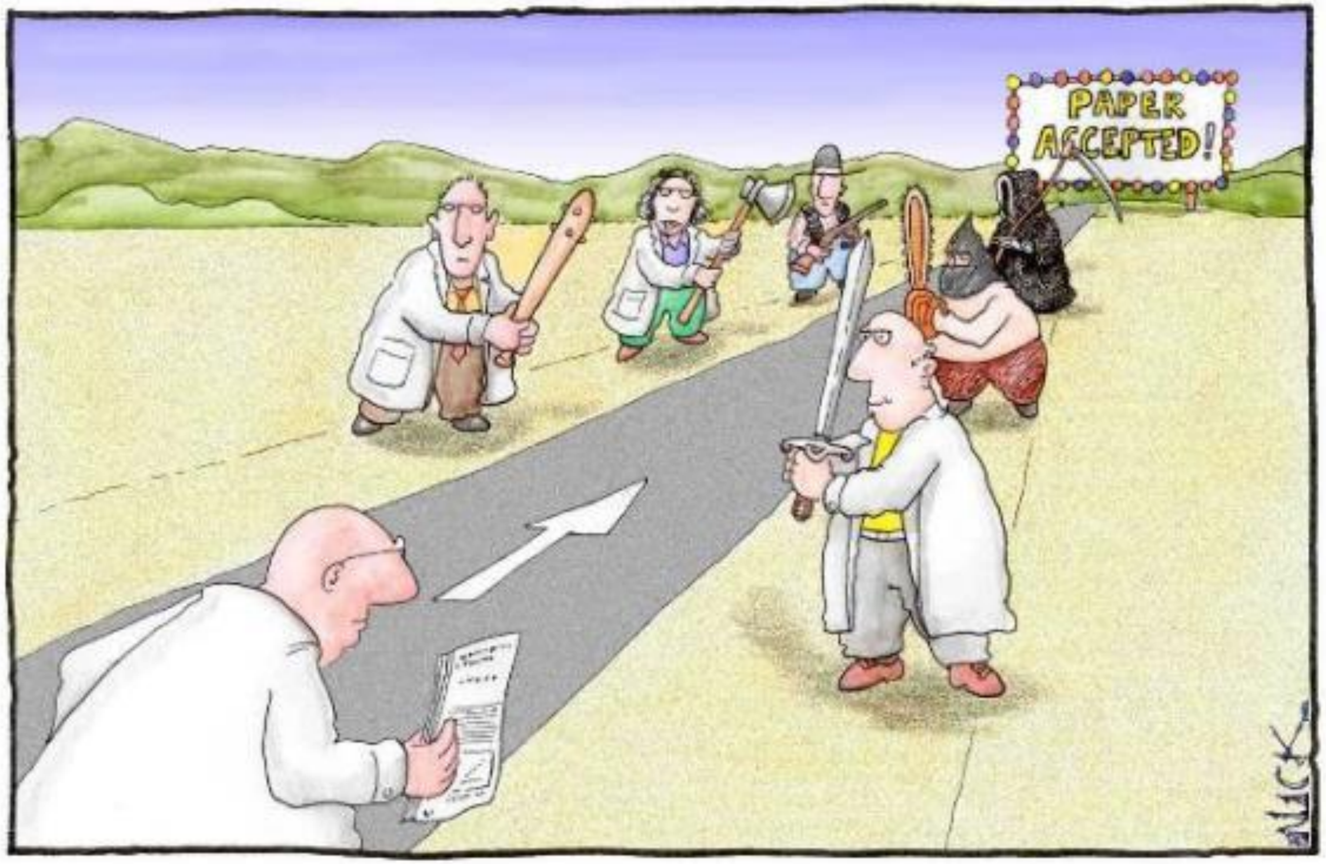
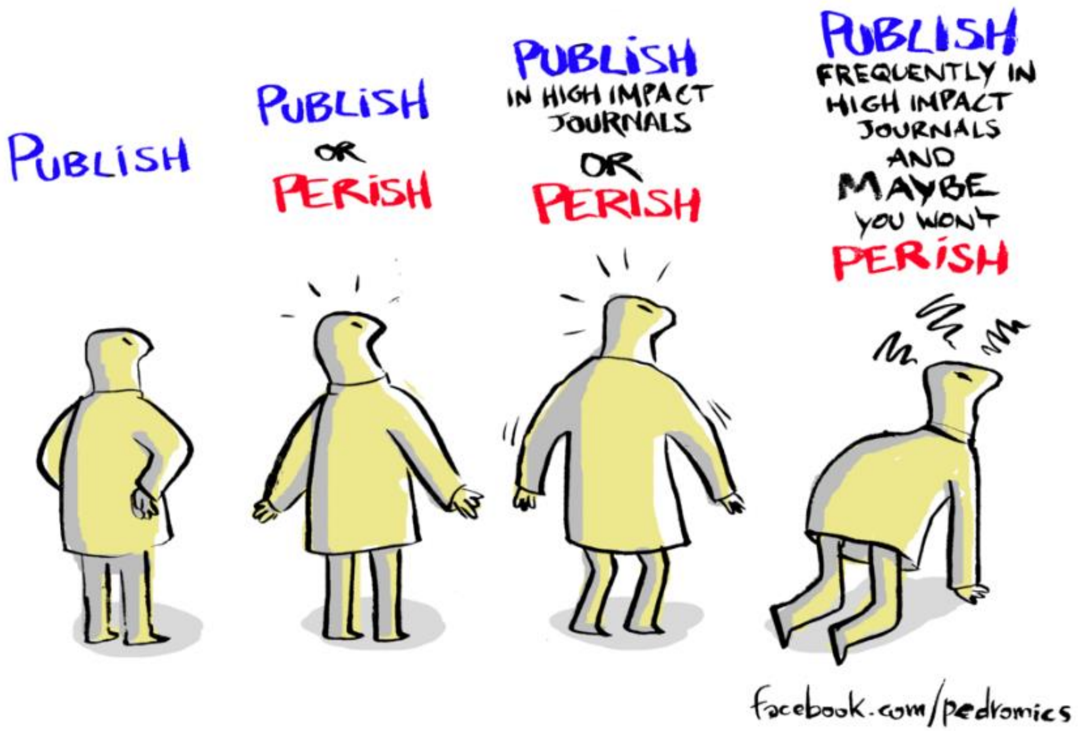
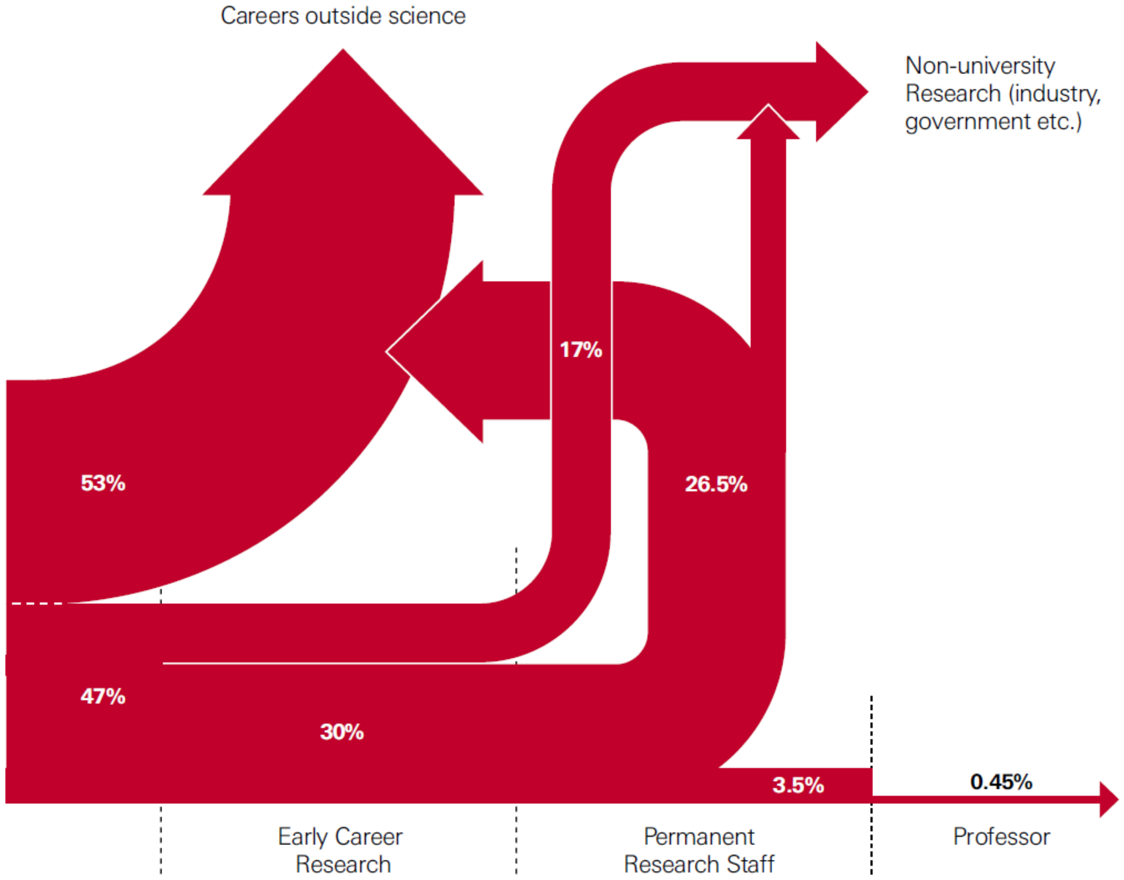


Image: Nick D. Kim, scienceandink.com. Used by permission

Adapted from: Anderson (2000) Normative Orientation of University Faculty and Doctoral Students https://doi.org/10.1007/s11948-000-0002-6; and: Mitroff (1974) Norms and counter-norms in a select group of the Apollo moon scientists https://www.doi.org/10.2307/2094423

There is no mystery why





Picture in the UK, post-PhD in science subjects, © The Royal Society, 2010
https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2010/4294970126.pdf

- Studied researcher assessment policies from 107 institutions across 7 countries
- Factors related to Open Science and Responsible Research and Innovation still very rare

	Austria	Brazil	Germany	India	Portugal	United Kingdom	United States
Service to profession	50%	100%	33%	58%	83%	100%	63%
Patents	33%	75%	67%	67%	67%	4%	34%
Review & editorial activities	17%	75%	75%	0%	50%	58%	40%
Engagement with industry	33%	33%	33%	25%	83%	62%	20%
Engagement with the public	17%	42%	25%	8%	100%	62%	17%
Publication quality	33%	0%	58%	33%	17%	79%	40%
Journal metrics	50%	42%	25%	67%	17%	12%	14%
Number of publications	67%	25%	25%	8%	33%	4%	17%
Engagement with policy makers	17%	33%	8%	0%	0%	54%	14%
Gender of reviewers	50%	0%	58%	0%	0%	0%	0%
Gender equality	67%	0%	42%	0%	0%	0%	0%
Citations	17%	0%	33%	8%	0%	17%	26%
Software	0%	75%	8%	0%	0%	0%	11%
Gender balance of reviewers	33%	0%	33%	0%	0%	0%	0%
Citizen science	0%	8%	8%	0%	0%	0%	6%
Open access	0%	0%	0%	0%	0%	0%	0%
Data	0%	0%	0%	0%	0%	0%	0%


QSS

an open access journal

Check for updates

Citation: Pontika, N., Klebel, T., Correia, A., Metzler, H., Knoth, P., & Ross-Hellauer, T. (2022). Indicators of research quality, quantity, openness and responsibility in institutional review, promotion and tenure policies across seven countries. *Quantitative Science Studies*, 3(4), 888–911. https://doi.org/10.1162/qss_a_00224

DOI: https://doi.org/10.1162/qss_a_00224

Peer Review: https://publons.com/publon/10.1162/qss_a_00224

Supporting Information: https://doi.org/10.1162/qss_a_00224

Received: 3 March 2022
Accepted: 25 October 2022

Corresponding Author: Tony Ross-Hellauer tross@know-center.at

Handling Editor: Ludo Waltman

Copyright: © 2022 Nancy Pontika, Thomas Klebel, Antonia Correia, Hannah Metzler, Petr Knoth, and Tony Ross-Hellauer. Published under a Creative Commons Attribution 4.0 International (CC BY 4.0) license.

The MIT Press

RESEARCH ARTICLE

Indicators of research quality, quantity, openness, and responsibility in institutional review, promotion, and tenure policies across seven countries

Nancy Pontika[1], Thomas Klebel[2], Antonia Correia[3], Hannah Metzler[4,5,6], Petr Knoth[1], and Tony Ross-Hellauer[2,7]

[1]Knowledge Media Institute, Open University, Milton Keynes, UK
[2]Open and Reproducible Research Group, Know-Center GmbH, Graz, Austria
[3]University of Minho, Braga, Portugal
[4]Complexity Science Hub Vienna, Vienna, Austria
[5]Medical University of Vienna, Vienna, Austria
[6]Institute for Globally Distributed Open Research and Education, Gothenburg, Sweden
[7]Open and Reproducible Research Group, Graz University of Technology, Graz, Austria

Keywords: indicators, open science, research assessment, responsible research and innovation, rewards and recognition

ABSTRACT

The need to reform research assessment processes related to career advancement at research institutions has become increasingly recognized in recent years, especially to better foster open and responsible research practices. Current assessment criteria are believed to focus too heavily on inappropriate criteria related to productivity and quantity as opposed to quality, collaborative open research practices, and the socioeconomic impact of research. Evidence of the extent of these issues is urgently needed to inform actions for reform, however. We analyze current practices as revealed by documentation on institutional review, promotion, and tenure (RPT) processes in seven countries (Austria, Brazil, Germany, India, Portugal, the United Kingdom and the United States). Through systematic coding and analysis of 143 RPT policy documents from 107 institutions for the prevalence of 17 criteria (including those related to qualitative or quantitative assessment of research, service to the institution or profession, and open and responsible research practices), we compare assessment practices across a range of international institutions to significantly broaden this evidence base. Although the prevalence of indicators varies considerably between countries, overall we find that currently open and responsible research practices are minimally rewarded and problematic practices of quantification continue to dominate.

Pontika, Klebel, Correia, Metzler, Knoth & Ross-Hellauer. 2022. Indicators of research quality, quantity, openness, and responsibility in institutional review, promotion, and tenure policies across seven countries. Quantitative Science Studies. 3 (4): 888–911. https://doi.org/10.1162/qss_a_00224

What you can do

- Perform more replication/reproduction of others' work
- Pre-register research protocols/hypotheses
- Share your data and code
- Use established reporting guidelines
- Preprint research for early feedback

nature human behaviour

PERSPECTIVE

PUBLISHED: 10 JANUARY 2017 | VOLUME: 1 | ARTICLE NUMBER: 0021

OPEN

A manifesto for reproducible science

Marcus R. Munafò[1,2*], Brian A. Nosek[3,4], Dorothy V. M. Bishop[5], Katherine S. Button[6], Christopher D. Chambers[7], Nathalie Percie du Sert[8], Uri Simonsohn[9], Eric-Jan Wagenmakers[10], Jennifer J. Ware[11] and John P. A. Ioannidis[12,13,14]

Improving the reliability and efficiency of scientific research will increase the credibility of the published scientific literature and accelerate discovery. Here we argue for the adoption of measures to optimize key elements of the scientific process: methods, reporting and dissemination, reproducibility, evaluation and incentives. There is some evidence from both simulations and empirical studies supporting the likely effectiveness of these measures, but their broad adoption by researchers, institutions, funders and journals will require iterative evaluation and improvement. We discuss the goals of these measures, and how they can be implemented, in the hope that this will facilitate action toward improving the transparency, reproducibility and efficiency of scientific research.

What proportion of published research is likely to be false? Low sample size, small effect sizes, data dredging (also known as *P*-hacking), conflicts of interest, large numbers of scientists working competitively in silos without combining their efforts, and so on, may conspire to dramatically increase the probability that a published finding is incorrect[1]. The field of metascience — the scientific study of science itself — is flourishing and has generated substantial empirical evidence for the existence and prevalence of threats to efficiency in knowledge accumulation (refs 2–7; Fig. 1).

Data from many fields suggests reproducibility is lower than is desirable[8–14]; one analysis estimates that 85% of biomedical research

The problem

A hallmark of scientific creativity is the ability to see novel and unexpected patterns in data. John Snow's identification of links between cholera and water supply[17], Paul Broca's work on language lateralization[18] and Jocelyn Bell Burnell's discovery of pulsars[19] are examples of breakthroughs achieved by interpreting observations in a new way. However, a major challenge for scientists is to be open to new and important insights while simultaneously avoiding being misled by our tendency to see structure in randomness. The combination of apophenia (the tendency to see patterns in random data), confirmation bias (the tendency to focus on evidence that is in line with our expectations or favoured explanation) and hindsight bias

Munafo, M.R. et al. 2017. "A Manifesto for Reproducible Science." Nat Hum Behav 1 (January): 0021. https://doi.org/10.1038/s41562-016-0021.

Recap

- **Open Science:** research that is openly available, accessible and reusable for everyone, encompassing a range of practices (OA, FAIR data, sharing of methods, citizen science, open peer review)
- **Reproducible research:** research that is transparent (protocols, data, code, etc.) such that it can be repeated, and that is free of questionable research practices such that results are robust

ORRG

Thank you!

v

Questions?

Contacts:

tross@know-center.at
https://mstdn.social/@tonyRH
https://www.linkedin.com/in/tonyrosshellauer/
https://twitter.com/tonyR_H

TU Graz

Know Center